
Chapter 3 — Network Clocking

Clocking in a Digital World

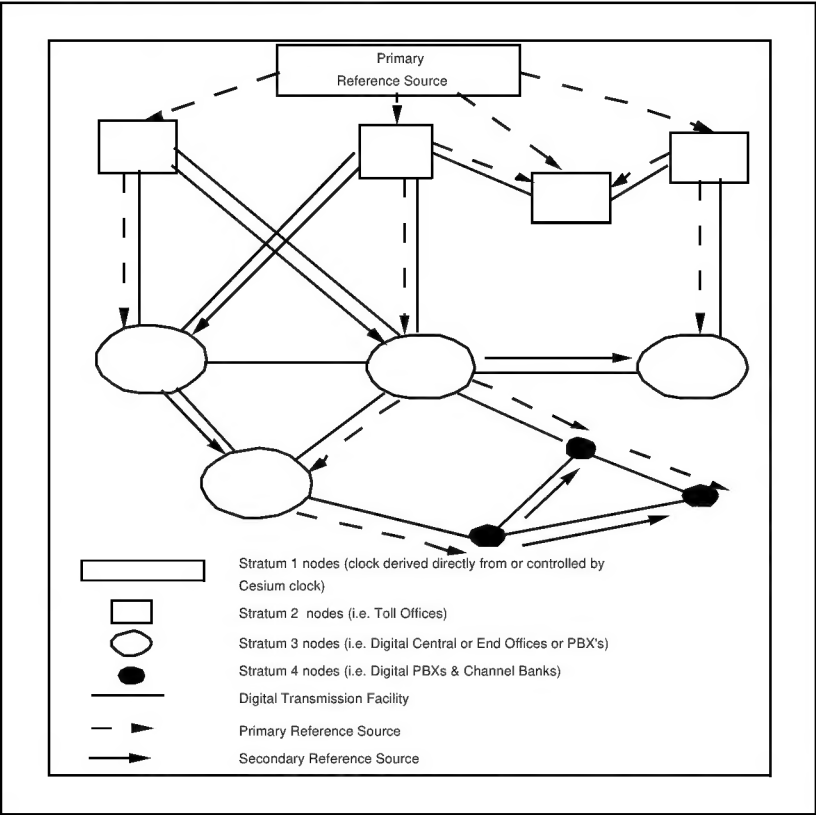
The Need for Synchronization

When digital signals are being transported over a communication link, the receiving end must operate at the same frequency as the originating end to prevent loss of information. This is referred to as link synchronization.

If both ends of a communication link are not in synchronization, data bit slips will occur and therefore a loss of data will result. In general, accurate timing is very important, but more importantly, synchronized timing is a must for reliable data transfer.

When only two Meridian 1 PBX systems are interconnected in an isolated private digital network, synchronization can be achieved by operating the two systems in a master/slave mode whereby one system derives its timing from the other. In a network of digital systems, however, slips can be better prevented by forcing all digital systems to use a common reference clock through a network clocking hierarchy (see Figure 53).

Figure 53
Hierarchical Synchronization



Synchronization Methods

There are two common methods of maintaining timing coordination between switching systems.

- a Plesiochronous operation:** nodal clocks run independently (free run) at the same nominal frequency. There will be frequency differences between clocks resulting in frame slips (see section “Frame Slips”). The magnitude of frame slips will be directly proportional to the frequency difference. Slips are inevitable but can be minimized by using very stable clocks and elastic stores or buffers. These buffers will be capable of absorbing a certain number of data bits to compensate for slight variances in clock frequencies.
- b Mesochronous operation:** nodal clocks are continuously and automatically locked to an external reference clock. With this method, frame slips can be eliminated if elastic stores are large enough to compensate for transmission variances. Mesochronous operation should be virtually slip free.

Whenever possible, the Meridian 1 PBX will operate in the Mesochronous mode by configuring the Clock Controller circuit cards to lock onto an external reference source. The above statement is true unless the Meridian 1 is used as a master in an independent/private network. An independent network has no digital links to a higher Node Category.

In an isolated private network, the Meridian 1 clock controller can operate in free run mode and act as a master clock to be tracked by other PBX systems in the private network.

North American Hierarchical Synchronization

Figure 53 provides a general view of a Digital Network Synchronization of clocks including the four stratum level Node Categories. Stratum 1 is the highest and most accurate, stratum 4 is the lowest. Meridian 1 Option 11 NTAK20AA clocking meets Node Category D Stratum 3 requirements. Option 11 NTAK20BA clocking meets CCITT stratum 4 requirements. Also shown are ways of providing a Secondary Clock Source while preventing timing loops that tend to cause instability in the synchronization of the digital network.

Timing Reference

Primary Timing Reference in the North American network is derived from a cesium beam atomic clock. The Canadian digital network, for example, is divided into two regions which interact plesiochronously, each with its own cesium atomic clock. Their common boundary is between Manitoba Telephone System and Bell Canada. The Eastern Region clock is located in Ottawa, while the Western region is located in Calgary. Any DS-1 signal leaving these switches is synchronized to the cesium oscillators.

Every digital node in Canada whether it is a Central Office, a Digital PBX with CO connectivity, or a digital Multiplexer should be able to trace their clock back to the cesium oscillator located in Ottawa or Calgary. This statement is true unless the Digital System is operating independently as a cell in plesiochronous operation.

In the U.S., a similar arrangement exists. The two primary clocks that support the U.S. network are located in St. Louis, Missouri. and Boulder, Colorado.

Node Categories/Stratum

In the North American digital network, nodes are synchronized using a priority master/slave method. Digital nodes are ranked in Node Categories A to E in Canada, and in Stratum levels 1 to 5 in the U.S. Each node is synchronized to the highest ranking node in its neighborhood with which it has a direct link.

Table 23
Node Categories

	Stratum 2	Stratum 3	Stratum 4
Accuracy	$\pm 1.6 * 10^{-8}$ Hz	$\pm 4.6 * 10^{-6}$ Hz	$\pm 3.2 * 10^{-5}$ Hz
Holdover	$1 * 10^{-10}$ per day	≤ 255 frame slips in 1st 24 hours	Not Required
Hardware Duplication	Required	Required (Note 1)	Not Required
MTIE During Rearrangement	MTIE ≤ 1 usec Phase Change Slope: ≤ 81 ns in any 1.326 msec	MTIE ≤ 1 usec Phase Change Slope: ≤ 81 ns in any 1.326 msec	No Requirement (Note 2)
Pull-in Range	$3.2 * 10^{-8}$ Hz	$9.2 * 10^{-6}$ Hz	$6.4 * 10^{-5}$ Hz
Dedicated Timing Required	Required	Required	Not required

Note 3: Non-duplicated clock hardware that meets all other stratum 3 requirements is referred to as stratum 3ND.

Note 4: Stratum 4 clock hardware that meets MTIE requirements during rearrangements is referred to as 4E.

The assignment of Node Categories/Stratums is shown in Table 24.

Table 24
Assignment of Node Stratums/Categories

AT&T Stratum	Canadian Node Category	Operating Equipment
1 (Located in St. Louis and Boulder)	A (Located in Calgary and Ottawa)	Regional Master with an associated cesium atomic clock.
2	B,C	International Gateway switch
3	D	Central Office / End Office, or digital PBX
4	E	Digital PBX or Multiplexers

Frame Slip

Digital signals must have accurate clock synchronization for data to be interleaved into or extracted from the appropriate timeslot during multiplexing and de-multiplexing operations. A frame slip is defined as the repetition or deletion of the 193 data bits of a DS-1 frame due to a sufficiently large discrepancy in the read and write rates at the buffer. Frame slips occur when clocks aren't operating at exactly the same speed.

When data bits are written into a buffer at a slightly *higher* rate than that at which they are being read, sooner or later the buffer overflows. This is a slip-frame deletion.

In the opposite situation, when data bits are written into a buffer at a slightly *lower* rate than that at which they are being read, eventually the buffer runs dry or underflows. This is also a slip-frame repetition.

Either occurrence is called a slip or a controlled slip. The Option 11 contains a buffer large enough to hold about 2 full DS-1 frames ($193 \times 2 = 386$). It is normally kept half full (1 frame). Slippage has impact on the data being transferred, as is shown in the table below, and all of the degradations shown in the table can be controlled or avoided with proper clock synchronization.

Table 25
Impact of slip on service types

Service	Potential Impact
Encrypted Text	Encryption key must be present.
Video	Freeze frame for several seconds. Loud pop on audio.
Digital Data	Deletion or repetition of Data. Possible Misframe.
Facsimile	Deletion of 4-8 scan lines. Drop Call.
Voice Band Data	Transmission Errors for 0.01 to 2 s. Drop Call.
Voice	Possible Click

Guidelines

Some key points to keep in mind when designing Network Synchronization:

- Where possible, the Master Clock Source should always be from a Node Category/Stratum with higher clock accuracy. For example, when the PBX is connected to the CO, the CO will be the Master and the PBX will be the Slave.
- The source should not itself be in free-run unless it is operating in a fully independent network where the source acts as a Master (see “Plesiochronous operation” in this chapter).
- When connecting two PBXs together with no CO connections, the most reliable PBX should be the Master. Reliability here refers to Dual CPU/Dual Clock, battery backup, and Stratum level of Clock Controller.

Note: QPC471 and QPC775 are not applicable to the Option 11.

- Avoid timing loops. A timing loop occurs when a clock is using as its reference frequency a signal that is traceable to the output of that same clock. The formation of such a closed timing loop will lead to frequency instability and should be avoided. Timing loops are sometimes unavoidable on the secondary clock reference source.
- Ensure all central offices/PBX links which are used as clock references have a traceable path back to the same stratum 1 clock source.

While it is beyond the scope of this guide to provide detailed Network Synchronization, the following figures will help illustrate some of the basic concepts to achieve stable clocking.

Figure 54
Isolated Private Network

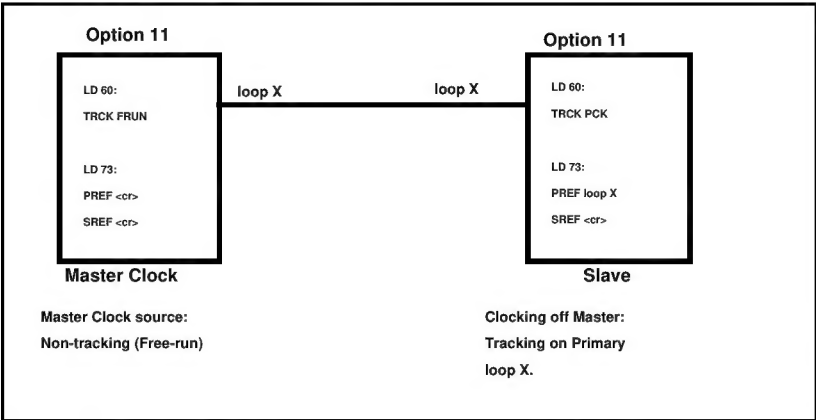
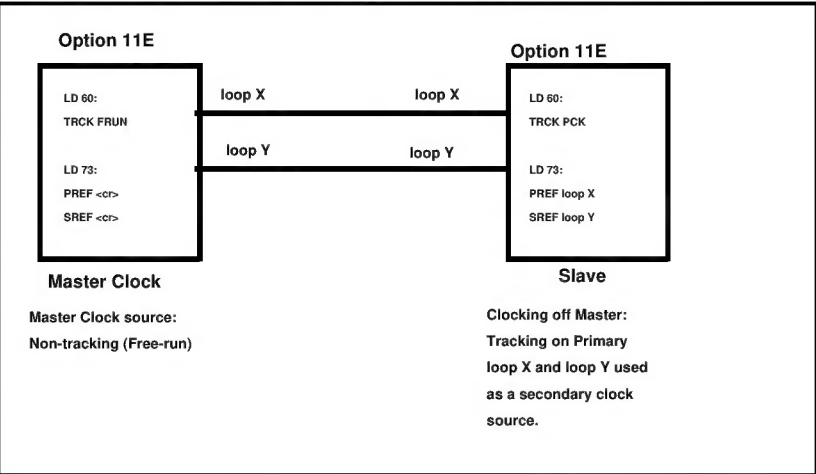


Figure 55
Isolated Private Network with Secondary Reference Clock



Comments:

- For tie lines between PBXs facilitated by a central office, clocking is derived from the PBX, not the CO.
- When a second Digital loop is available, it can be used as a Secondary Clock source in case the Primary Source fails.

Figure 56
Clocking Hierarchy referenced to a Public Network Master Clock

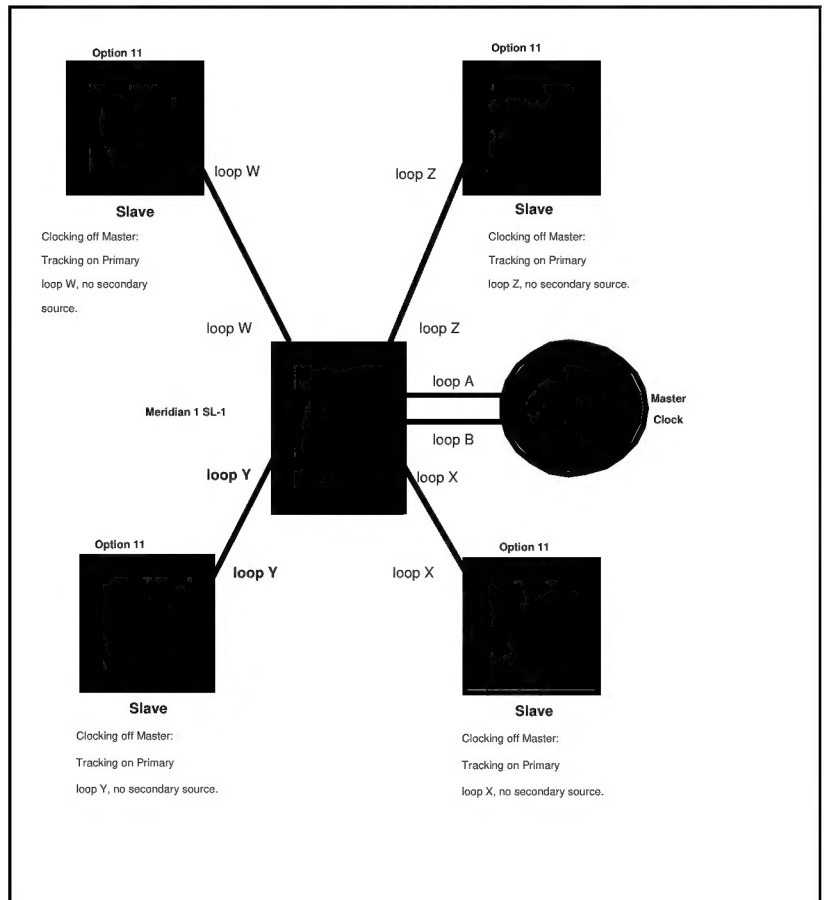
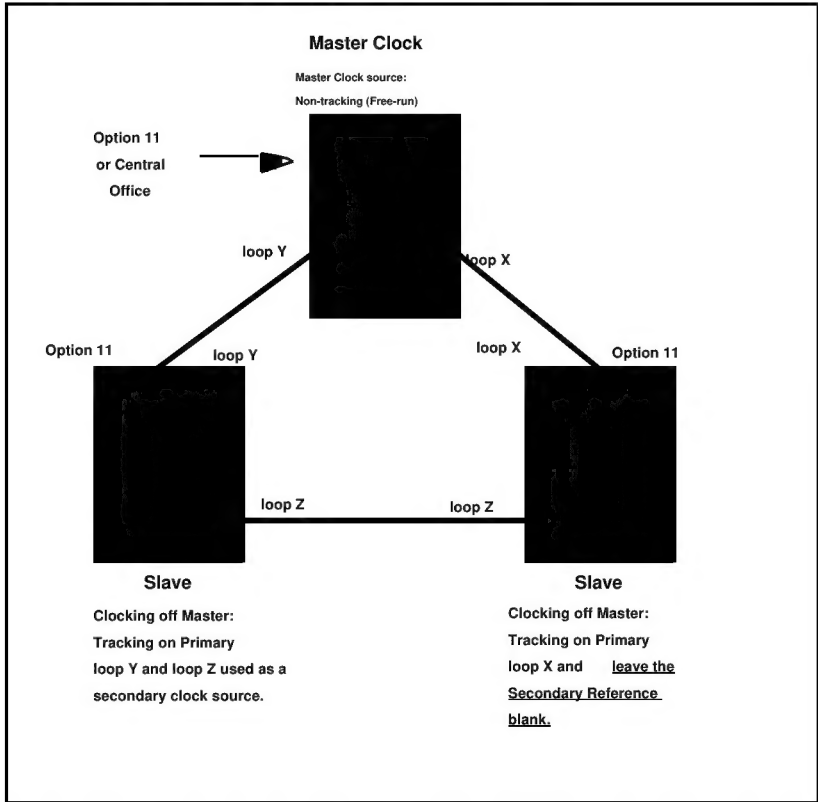


Figure 57 shows a STAR arrangement: one Hub PBX is linked to the Central Office and all other PBXs are connected as slaves. When a second Digital loop from the Option 11 which forms the hub of this network becomes available, it can be used as a Secondary Clock Source in case the Primary Source fails.

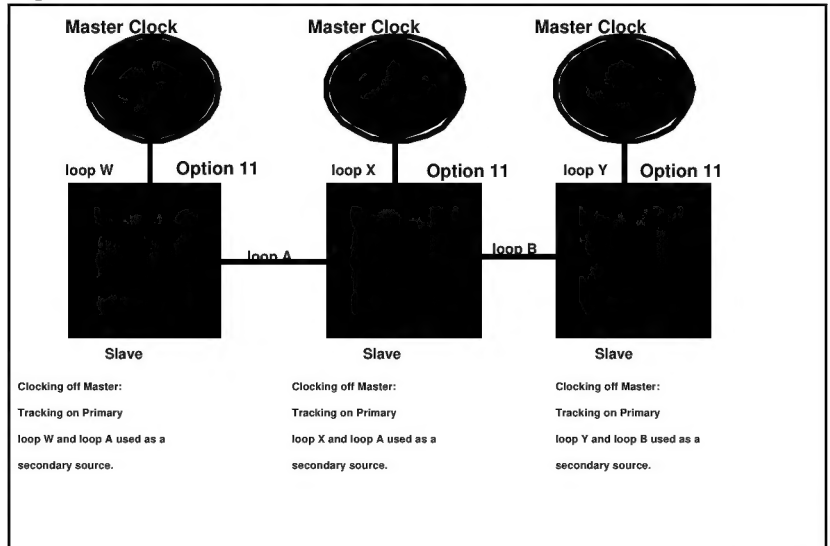
Figure 57
Alternate Clocking from the same CO



A digital connection to the Central Office may exist (i.e. Loops X and Y). When a second Digital loop from the CO or Master Meridian 1 becomes available, it can be used as a Secondary Clock Source in case the Primary Source fails.

To avoid timing loops, the most reliable slave system should not have a Secondary Clock Source (SREF= <cr>). In Figure 58, this is illustrated by the node which supports loops X and Z.

Figure 58

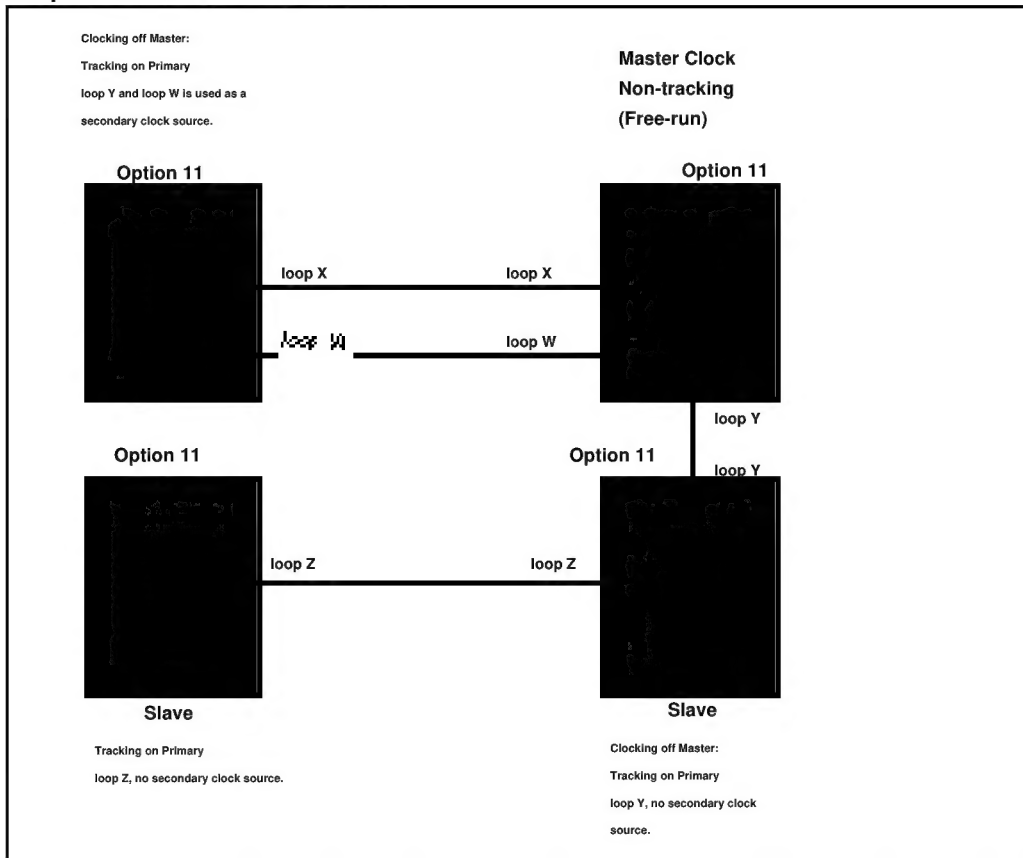


Digital connections to the Central Office do exist. When a second Digital loop from the CO becomes available, it can be used as a Secondary Clock Source in case the Primary Source fails.

Slaves can track on each other as a secondary source since the chances of both links to the Central Offices going down at the same time are very unlikely.

Note: All central offices must have a path back to the same stratum 1 source.

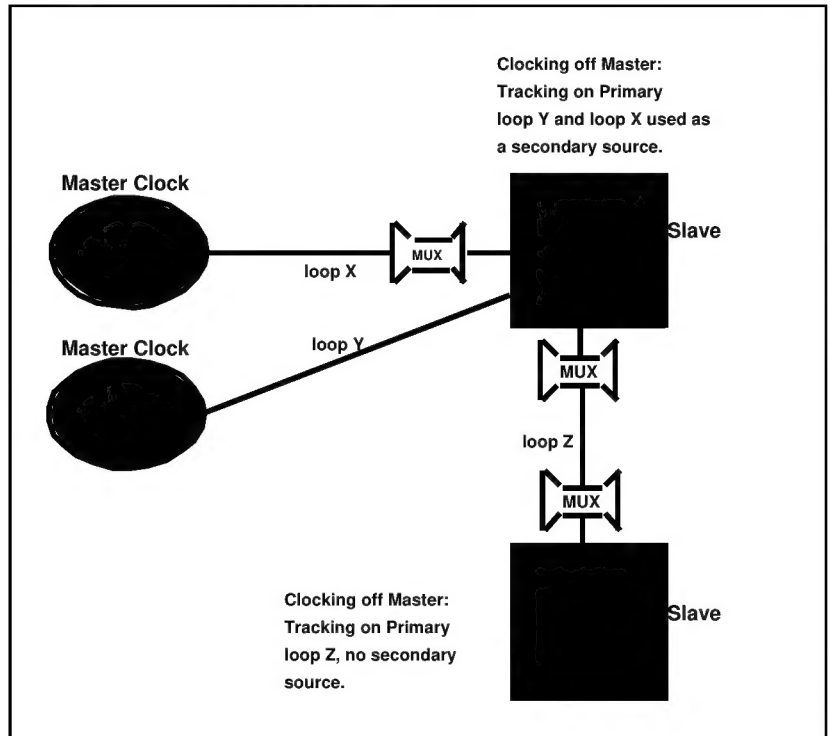
Figure 59
Complex Isolated Private Network



Digital connections to the Central Office do not exist. If it does, the PBX connected to it will track off the C.O. and will in turn be used as a clock source to other nodes.

When a second Digital loop from the Master Meridian PBX becomes available, it can be used as a Secondary Clock Source in case the Primary Source fails.

Figure 60
Network Clocking with MUXs



The direct connection to the CO (without a MUX) should be used as a primary clock reference since there is the least amount of hardware involved. The MUX must pass the clock and not generate its own clock; in other words, it must also be a slave (not Free Run). Synchronized clocking is required.